PREEQUILIBRIUM EMISSION IN ^{90}Zr, $^{208}Pb(p,n)$ REACTIONS

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Preequilibrium (PE) neutron emission is the main de-excitation channel resulting from projectile proton energies exceeding 35-40 MeV. Angular distributions of the spectral continuum, in particular in their backward parts, give informations on those PE reaction mechanisms that cannot be represented in semiclassical nucleon-nucleon collision pictures;[1] in addition, the structure of the energy spectra at low excitation ($U < 10$ MeV) may reflect the $1p1n^{-1}$ residual states participating. Also, with the knowledge of the absolute spectral shapes of (incoherent) PE contributions under forward angles, the missing GT strength[2] may be searched for in the continuous part ($U \leqslant 50$ MeV).

Among the theoretical quantum mechanical treatments of PE emission, the one of Feshbach et al.[3] has shown good overall agreement with (p,n) and (^{3}He,n) data for projectile energies up to 45 MeV. PE data of (p,n) reactions with high incident ($E_p > 80$ MeV) energies would allow a challenging test of both, models and theories, of the angular and spectral distribution of particles provided they extend to angls > 90° and are taken under optimized background conditions.

We have started (E275, 10 shifts) a study of the (p,n) reaction on ^{90}Zr and ^{208}Pb with self-supporting targets (^{90}Zr: 77 and 112 mg/cm^2, ^{208}Pb: 51 and 175 mg/cm^2). Measurements have been performed in the beam swinger area with the new stripper loop reducing the burst repetition rate by a factor 60 to approx. 0.5 MHz at an average beam intensity of 10-2° nA. Neutron detection was achieved with new detectors of the type investigated by Finlay et al.;[4] they are of cylindrical shape (12" ϕ x 8"), filled with NE213 and showed good timing (Δt = 2-2.5 ns) and excellent n-γ discrimination characteristics. Five time-of-flight paths have been installed at angles 0° (detector D1, s = 46.6 m), 24° (s = 38.4 m) and 45° (s = 26.1 m) by means of huts; two detectors were placed at 106° (s = 14.9 m) and 144° (D5; s = 11.1 m) in the cooler building. In three groups of runs with the beam swinger being set to 0°, 11° and 24°, the angular range 0°-144° was covered with 13 different and about equidistantly spaced angular positions. The three backward detectors were vetoed against cosmics with scintillator paddles.

Each run was supplemented by a background run with a shadow bar of an absorbing length 5λ (for E_n = 100 MeV). Additionally background studies were performed for testing purposes with blank target frames. Figure 1 shows continuous neutron energy spectra converted to absolute values with the efficiency data of Ref. 5 they are not yet corrected for flux absorption along the TOF paths (≤ 30% for $E_n > 20$ MeV). For the four forward detectors, the shadow bar runs represent at most a 10% correction and drop below the 1 µb/sr MeV level outside the physical region En ≤ 74 MeV. No explanation can be given for the structure visible in the background run at Θ = 45°; it does not show up at Θ = 48° covered by a different

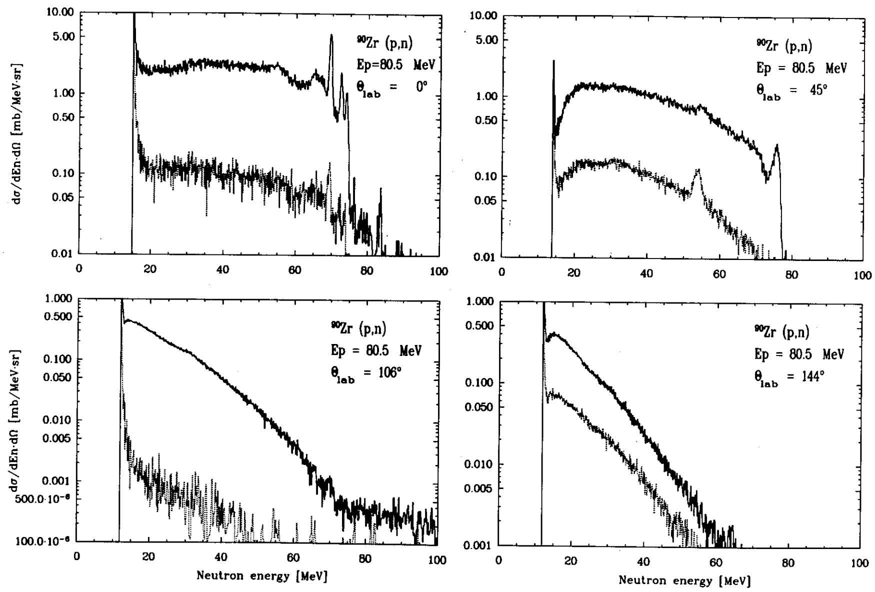

Figure 1. Laboratory energy spectra of neutrons from ^{90}Zr(p,xn) obtained without (solid lines) and with (dashed) shadow bars and the 0° beam swinger setting.

beam swinger setting and detector. The differences between each two spectra in the unphysical region indicate that the shadow bars were either oversized in diameter or placed too close to the detectors. Altogether, however, the background conditions for these detectors give rise to the hope that reliable effect spectra can be obtained down to the 1-10 μb/sr MeV level.

The situation is different for the most backward detector (Θ = 144° in Fig. 1); this one is fairly close to the upstream beam line and suffers from a high background compared to a low neutron yield coming directly from the target. Here, additional individual detector shielding is mandatory.

A selection of resulting energy spectra is given in Fig. 2. It shows the smooth transition from hard and almost isotropic spectra at very forward angles, with well resolved transitions to low lying states and resonances (detector D1, Θ = 0° and 11°), to much softer ones observed in the backward hemisphere. The g.s. transition from ^{90}Zr, ^{208}Pb as well as from the

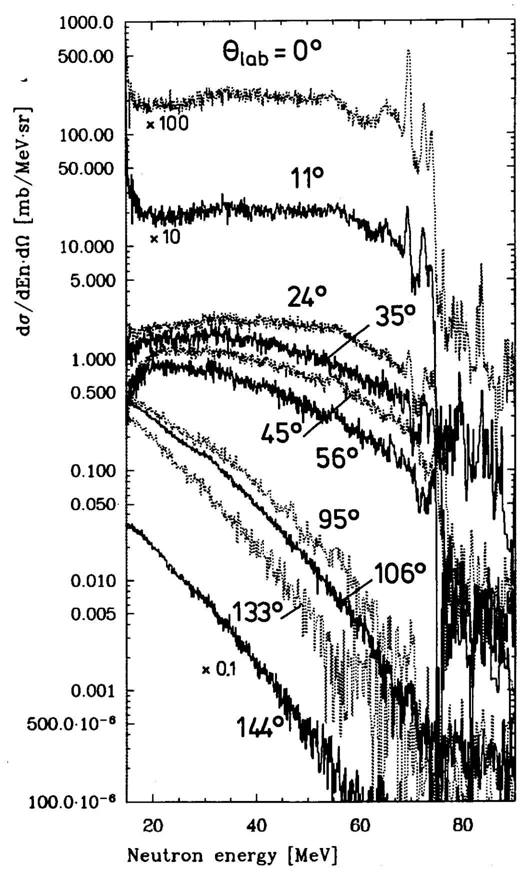

Figure 2. Resulting neutron energy spectra after subtraction of background. Please note scaling for Θ_{lab} = 0°, 11°, 144°.

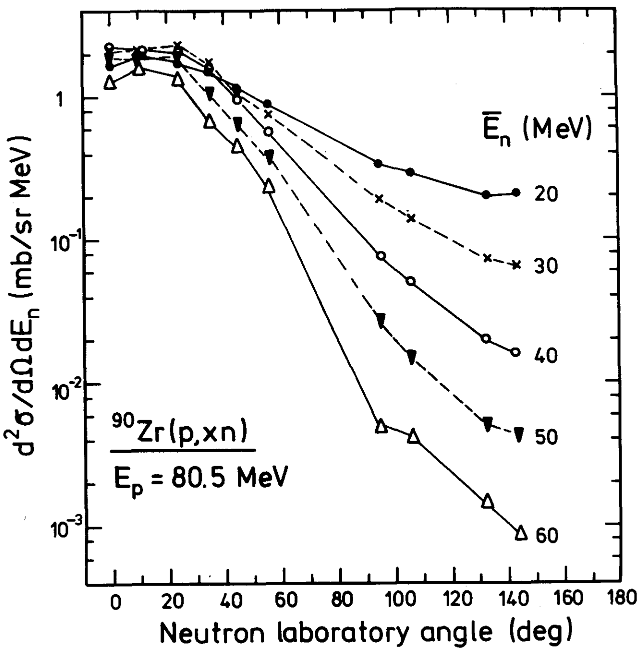

Figure 3. Angular distributions for 0.5 MeV neutron energy bins centered around the laboratory energies E_n.

calibration targets ^7Li and ^{nat}C will help to check the calculated efficiencies. From this type of data we hope to extract angular distributions in the region 10 MeV $\leqslant$ U $\leqslant$ 60 MeV that can be followed over up to three orders of magnitude. Figure 3 shows preliminary results for several neutron energies E_n between 20 and 60 MeV.

Further data analysis is in progress. The experiment will be continued for ^{90}Zr and ^{208}Pb with E_p = 160 MeV projectiles.

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1) M. Blann, W. Scobel and E. Plechaty, Phys. Rev. C 30, 1493 (1984).

2) P. Osterfeld et al., Phys. Rev. C 31, 372 (1985).

3) H. Feshbach, A. Kerman and S.E. Koonin, Ann. Phys. (N.Y.) 125, 429 (1980).

4) R.W. Finlay et al., Nucl. Instr. Meth. 198, 197 (1982).

5) R.C. Cecil et al., Nucl. Instr. Meth. 161, 439 (1979).